

Free Executive Summary

Evaluation of Chemical Events at Army Chemical Agent Disposal Facilities



Committee on Evaluation of Chemical Events at Army Chemical Agent Disposal Facilities, National Research Council

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Executive Summary

The National Research Council was asked by the Army to form a special, ad hoc committee to investigate whether incidents involving chemical warfare materiel stored, processed, and destroyed at the two operational Army chemical demilitarization sites provide useful information for the safe operation of future sites.¹ To discharge its responsibility, the Committee on Evaluation of Chemical Events at Army Chemical Agent Disposal Facilities examined information on all forms of chemical events and incidents that occurred through the summer of 2001 at the Johnston Atoll Chemical Agent Disposal System (JACADS)² site in the Pacific Ocean and at the Tooele Chemical Agent Disposal Facility (TOCDF) in Utah. Information on these events was obtained from sources within the government and from a full range of public sources.

The committee concluded that safe chemical weapons disposal operations are feasible at the new facilities scheduled to begin operating at Anniston, Alabama; Umatilla, Oregon; and Pine Bluff, Arkansas, if their management is diligent in setting and enforcing rigorous operational procedures, in providing comprehensive training, in establishing a strong safety culture encompassing all plant personnel, and in absorbing programmatic lessons learned from the first two operational facilities, JACADS and TOCDF. The committee believes that many of the observations and recommendations made in this report are applicable to all demilitarization facilities, including those that may not use incineration. No evidence derived from previous chemical events causes the committee to doubt that the new incinerator technology

plants or the disposal processes they will employ can be operated safely and effectively. The committee joins predecessor committees (NRC, 1994, 1997) of the National Research Council that have found that the risk to the public and to the environment of continued storage overwhelms the potential risk of processing and destruction of stockpiled chemical agent.

Recommendation 1. The destruction of aging chemical munitions should proceed as quickly as possible, consistent with operational activities designed to protect the health and safety of the workforce, the public, and the environment.

THE CHEMICAL DEMILITARIZATION CHALLENGE

How can we safely destroy the current U.S. stockpile of chemical weapons within the time constraints imposed by a dangerous and deteriorating stockpile (U.S. Army, 2001d) and mandated by law? Under congressional mandate (Public Law 99-145), the Army instituted a sustained program to destroy elements of the chemical weapons stockpile in 1985 and extended this program to destroy the entire stockpile when Congress enacted Public Law 102-484 in 1992. The stockpile then included more than 31,000 tons of nerve and blister agents deployed in several million individual munitions and containers. In 1997, the Congress reiterated this commitment by ratifying the Chemical Weapons Convention.³

The U.S. Army, through its Program Manager for Chemical Demilitarization (PMCD), began active destruc-

¹The statement of task is included in the preface.

²Johnston Island, southwest of Hawaii, was the site at which the U.S. Army gathered chemical weapons withdrawn from overseas locations. JACADS, the initial stockpile facility, began destruction activities in 1990 and completed processing in November 2000. Planning for closure operations is currently under way.

³Formally known as the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (P.L. 105-277), the CWC requires the destruction of chemical weapons in the stockpile by 2007 and any non-stockpile weapons in storage at the time of the treaty ratification (1997) within 2, 5, or 10 years of the ratification date, depending on the type of chemical weapon or on the type of chemical with which an item is filled.

tion of overseas chemical weapons stockpiles at JACADS in 1990. In 1996, PMCD commenced destruction of the continental U.S. chemical weapons stockpile at TOCDF, located at the Deseret Chemical Depot (DCD) in Tooele County, Utah. The disposal of the stockpile on Johnston Island was completed in November 2000, and by September 2001 nearly 40 percent of the chemical agent at Tooele, the site of the largest stockpile, had been destroyed. Between these two facilities, approximately 23 percent of the original chemical weapons stockpile had been disposed of by the end of the summer of 2001.

During the 10 years of JACADS operation and the first 5 plus operational years at TOCDF, a number of operational upsets or incidents occurred (U.S. Army, 2001c). Some resulted in chemical agent penetrating into normally agent-free areas where workers could be exposed. In others, improper operating procedures in agent-contaminated areas led to actual or potential worker exposure. Further, in a few of these events, very small amounts of agent were actually released outside the building into the ambient atmosphere.

JACADS and TOCDF are first- and second-generation chemical demilitarization facilities based on the disassembly of chemical munitions and destruction of both the chemical agent and the associated energetic munitions, as well as the decontamination of metal containers in a suite of specialized incinerators. In 2002 and 2003, third-generation facilities based on the same disassembly and incineration technologies are scheduled to commence operation at three of the largest remaining stockpiles at Army depots in Anniston, Alabama; Umatilla, Oregon; and Pine Bluff, Arkansas.

This report responds to congressional, Army, and public concerns by:

- Providing a context for evaluating the significance of chemical events,
- Illustrating methods for the analysis of chemical events,
- Analyzing chemical events at the two initial chemical demilitarization sites as of September 2001, and
- Providing recommendations for minimizing and managing potential future chemical events.

Dismantling and destroying chemical weapons is inherently hazardous, but the Program Manager for Chemical Demilitarization has incorporated extraordinary safety precautions into both plant design and personnel training (NRC, 1996, 1997, 1999a). The chemical demilitarization incineration plants are virtual fortresses built to withstand the consequences of accidents, and, to date, releases of chemical agent from these facilities have been rare, isolated events involving only small amounts of agent, even under upset conditions (NRC, 1996, 1997, 1999a). State-of-the-art quantitative risk assessments have determined that the major hazard to the surrounding communities arises from potential releases of agent from stockpile storage areas, not the de-

militarization facilities (U.S. Army, 1996a; NRC, 1997; see also Chapter 1 and Appendix E). However, given the inherent complexity of the chemical demilitarization task at the assembled weapons stockpile sites, it is almost certain that new problems will continue to arise, particularly from aging and deteriorating weapons and the challenges of demilitarization plant closure and decommissioning. There will be future “chemical events,” and serious consequences to both plant personnel and surrounding communities cannot be ruled out.

WHAT ARE CHEMICAL EVENTS?

Data and Definition

To determine the frequency and nature of chemical events at JACADS and TOCDF, the committee requested that PMCD provide information on all incidents at the two sites that the Army considered to be chemical events. PMCD provided data on 81 separate incidents (39 from June 1990 through December 2000 at JACADS and 42 from August 1996 through May 2001 at TOCDF; see Appendix B) and included independent investigation reports for the most serious events. The committee also solicited and received information on actual or suspected incidents from concerned citizens, local and state officials, an organization opposed to incineration as a disposal means, and current and former facility employees (see, for example, Appendix C). Much of this information was gathered during visits to PMCD, JACADS, TOCDF, and the recently constructed Anniston Chemical Agent Disposal Facility.

To gain a perspective on the release of chemical agent to the environment during chemical demilitarization activities, the committee obtained data from the U.S. Army Soldier and Biological Chemical Command on the rate and severity of leaks from 1990 through 2000 from the chemical weapons stockpiles stored at Johnston Island and Deseret, Utah (U.S. Army, 2001d).

The committee determined that current Army criteria for classifying events at storage and demilitarization facilities are ambiguous and allow the local depot commander latitude to define as a chemical event accidents or incidents that do not involve release of chemical agent.⁴ Other incidents that clearly involved chemical agent were not defined

⁴For example, Army Regulation 50-6, on chemical surety, provides specific examples of chemical events which the committee judges to be so broad as to invite widely divergent interpretations by local Army depot commanders, such as example number 7: “Any malfunction or other significant activity at a chemical demilitarization plant that could reasonably be expected to cause concern within the local community or the press, or that in the judgment of the local facility or installation management or leadership could cause embarrassment to the U.S. Army” (U.S. Army, 1995).

as chemical events, because the escaped agent remained within the plant's engineering controls.

For the purposes of this report, the committee determined that a *chemical event* is any incident associated with chemical demilitarization operations that results in an actual or potential release of chemical agent.

Recommendation 2. The Army should establish a consistent set of criteria to be used by all chemical-agent-processing facilities to ensure uniformity in the classification of events, and to facilitate event analysis and comparison.

Risk Assessment

The demilitarization facilities contain relatively little chemical agent at any one time, and that agent is under stringent engineering controls in the demilitarization facility. The published quantitative risk assessment for TOCDF (U.S. Army, 1996a) makes clear that by far the greatest risk to the public arises from accidental or deliberate detonation of stored chemical munitions and the accompanying release of large amounts of chemical agent to the environment. Although after the events of September 11, 2001, the Army delayed publication of its quantitative risk assessments for the third-generation chemical demilitarization facilities, the committee has ascertained that the new risk assessments confirm the dominance of the risk of continued chemical munitions storage. The committee concluded that, in the post-September 11, 2001, world, the threat of terrorism and sabotage would likely be focused in the storage facilities, rather than the demilitarization facilities.

The committee further finds that quantitative risk assessments (QRAs) and health risk assessments (HRAs) are critical inputs to the dialogue necessary to ensure adequate public involvement in and understanding of chemical demilitarization activities. Maintaining a prudent balance between the public's right to know the risks they face and the need to protect sensitive information will be an ongoing challenge for the chemical demilitarization program. Without adequate risk information available to the public, it will be difficult to develop or maintain the level of public trust necessary for PMCD to accomplish its mission.

Recommendation 3. The Army should continue its practice of making available to the public the results of its quantitative risk assessments and health risk assessments for each chemical demilitarization site.

The committee also found that the QRAs provide a valuable framework for managing the risk from chemical events, including events arising from sabotage, terrorism, and war, by placing events in the context of their impact on safety.

Recommendation 4. The quantitative risk assessment (QRA) for each chemical demilitarization site should be it-

erative. Actual chemical events should be used routinely to test the completeness of the QRA, which should be routinely utilized to hypothesize the frequency and consequences of chemical events. The Program Manager for Chemical Demilitarization and the U.S. Army Soldier and Biological Chemical Command should use the QRAs to evaluate measures to control future chemical events. The Army should also consider using QRAs to examine scenarios associated with sabotage, terrorism, and war.

MONITORING CHEMICAL AGENT

The committee also reviewed the chemical agent monitoring procedures at incinerator-based demilitarization facilities. It determined that because the monitoring levels used by PMCD are very conservative and highly protective of worker and public health and safety, there are frequent false positive alarms, as well as alarms for actual events that pose no measurable threat to workers or the public. These conservative stack-monitoring thresholds ensure that no significant amounts of agent can be exhausted into the ambient air without the facility alarming and the agent incineration feed automatically terminating. In-plant air breathed by unmasked workers and the output of the scrubbing system for air exiting the chemical demilitarization plant are monitored at similarly conservative thresholds.

Recommendation 5. The Army should maintain conservative chemical demilitarization exhaust stack and in-plant airborne agent exposure thresholds. If current limits for exposure to stockpiled chemical agents are further reduced, the Army should not further reduce existing monitoring thresholds unless chemical agent monitors can be made both more sensitive and more specific so that lower thresholds can be instituted without significant increases in false positive alarm rates or unless health risk assessments demonstrate that lower thresholds are necessary to protect workers or the public.

However, the high rate of false positive alarms seems to be causing a "crying wolf" mentality whereby some operational personnel tend to discount alarms until they have been confirmed by laboratory analyses. PMCD must make it clear that properly responding to alarms is more important than production and, at the same time, show that it is trying to solve the underlying problem by actively developing better instruments. The committee notes that PMCD's operating procedures require that all alarms be treated as real until it has been demonstrated by laboratory analyses that they were not triggered by real chemical events.

Recommendation 6. To reduce the rate of false positive alarms for both airborne and condensed-materials agent contamination, the Program Manager for Chemical Demilitarization and the relevant Department of Defense research and development agencies, such as the Army Research Office,

the Army Research Laboratory, the Defense Advanced Research Projects Agency, and the Defense Threat Reduction Agency, should invigorate and coordinate efforts to develop chemical agent monitors with improved sensitivity, specificity, and time response. These efforts should be coordinated with, and take advantage of, the increased level of interest in and increased resources available for developing chemical weapons detectors for homeland defense.

CHEMICAL EVENTS ANALYSES

In analyzing past chemical events, the committee found that the basic design of the incineration-based demilitarization facilities and the processes used to disassemble and destroy chemical weapons and to dispose of residue and waste streams (see Appendix A) are fundamentally sound. The committee further found that the investigation of chemical events and incidents at demilitarization facilities has been straightforward and honest. However, the committee observed that future investigations could benefit from the use of methodologies such as causal tree analysis (where events are related to the final outcome) and human factors engineering (where data on human performance are related to the causal tree). Such methodologies would result in uncovering and understanding the complete set of those factors found to have contributed to each incident.

Recommendation 7. Incident investigation teams should use modern methodologies of incident investigation routinely at all chemical demilitarization sites to help uncover a broader set of causal and contributing factors, and to enable greater understanding of the interrelationships between and among these factors. Experts in human performance modeling should be included on any incident investigation team. A standing incident review board at each site should be established to identify chemical events requiring in-depth investigation and to ensure that the lessons learned appropriately influence ongoing operations. These boards would meet regularly to review accidents and incidents, including chemical events, and would be fully informed of any findings and recommendations made by chemical event investigation teams.

In its analysis of JACADS and TOCDF chemical incidents and events, the committee observed that repeating patterns of causal factors occurred across the range of incidents, from minor to severe. In particular, deficiencies in standard operating procedures (SOPs), design failures, and understandable, although inappropriate, assumptions (mind-set) of operations personnel contributed to almost all of the incidents investigated in depth. Repeating patterns of causal factors in most incidents did not appear to have been used by management to generalize incident findings beyond the immediate context of each incident.

Recommendation 8a. The Program Manager for Chemical

Demilitarization should analyze all chemical-agent-related incidents at chemical demilitarization plants for patterns of causal factors and should institute program-wide actions to address the causes found.

The programmatic lessons learned (PLL) database compiled by PMCD is a large undertaking and should help capture lessons from past chemical events and help prevent the recurrence of similar events. PMCD is to be commended for creating and maintaining the PLL database. However, information in the PLL database is relatively hard to use and is not prioritized. The data would be more useful if it were organized in a manner that included a system for prioritizing the data. The data may contain patterns that underlie several events and that could be found by “mining” the data for these connections. This information would improve the capability for broad generalization of specific information from an individual incident.

Recommendation 8b. Any improvements made in investigation procedures should become part of a systematically organized programmatic lessons learned (PLL) database that makes information easier for the non-expert to find and/or use. This can include prioritization and developing a drop-down “tree” list. Lastly, the Program Manager for Chemical Demilitarization should ensure that, at the plant level, the data are available to, known by, and useful to operations personnel. The proposed contractor for the PLL program should address these issues. For the program to be useful all stakeholders need to buy into its use and structure.

CHEMICAL EVENT IMPACTS

The committee observed that the computer models used to model accidental chemical releases in Army and local government emergency operation centers (EOCs) are representative of the state of the art as of the late 1970s. The Gaussian plume dispersion modeling techniques embedded in the D2PC computer model used to predict agent emission plume extent have more current and accurate implementations. Adoption of more modern and more accurate emission plume models seems to have been delayed by the failure to integrate better plume models into standard Chemical Stockpile Emergency Preparedness Program (CSEPP) emergency response models.

Recommendation 9a. Stockpile sites that still use the D2PC computer model should, at a minimum, upgrade their emergency response models to take advantage of the improved capabilities available in the D2-Puff model. Consideration should be given to testing and possibly optimizing the D2-Puff model at each site by performing tracer release experiments under a variety of meteorological conditions.

Recommendation 9b. The Chemical Stockpile Emergency

Preparedness Program should undertake a continuing evaluation of alternative approaches to modeling the release and impact of chemical agents.

Recommendation 9c. Accurate agent plume dispersion modeling capability should be coupled with timely communication of results and appropriate responses to the stockpile site and surrounding communities.

The committee also determined that communications during and after incidents and events have not always occurred as intended between and among the various stakeholders. The lack of an override function or a hot line dedicated to notification that an event has occurred has led to inadequate communication during chemical events. For example, the lack of notification and warning between DCD, Tooele County, and other Utah responsible agencies was caused in part by a lack of coordination between the Federal Emergency Management Agency's (FEMA's) CSEPP and the Army's Emergency Operations Center, and in part because of DCD's prevailing attitude that its emergency management responsibilities "end at the fence." This perspective, if carried to other communities where chemical demilitarization facilities are to be operated, can endanger the ability to provide an effective, coordinated emergency response to incidents. The memorandum of understanding for information exchange recently agreed to by the DCD and Tooele County (see Appendix G) could serve as a model for every community with a chemical weapons stockpile, to ensure very close oversight of the disposal plant's operations.

Recommendation 10a. Chemical demilitarization facilities should develop site-specific chemical event reporting procedures and an accompanying training program that tests and improves the implemented procedures and communication system.

Recommendation 10b. The standing incident review board recommended by the committee for each site should include a qualified member of the public who can effectively represent and communicate public interests.

Recommendation 10c. Each chemical demilitarization site should consider the establishment of a reporting and communication memorandum of understanding (MOU), of the sort developed between the Desert Chemical Depot and Tooele County, which specifies reliable and trusted means of alerting and informing local officials about chemical events. These MOUs should be designed to permit ready evaluation and updating of the terms of the MOU to take full advantage of learning across the array of chemical demilitarization sites.

Recommendation 10d. The Army Emergency Operations Centers and the Chemical Stockpile Emergency Prepared-

ness Program should establish a stronger capability and capacity for the coordination of training, equipment, and plans necessary to respond effectively to an emergency incident, and the commitment to do so in a coordinated and cooperative fashion. Additionally, the Army should continue its program of outreach—including listening to public concerns and responding to them, as well as engaging in more conventional public information efforts—to both the public and the relevant government oversight agencies to enhance general understanding of the chemical demilitarization program.

A major chemical event can result in several months of lost chemical munitions processing time. Multiple incident investigations and responses have led to additional delays in restarting operations when incidents have led to plant shutdown. All aspects of such investigations and resumption of operations should be accelerated consistent with safe operations.

Recommendation 11. All stakeholders and involved regulatory agencies should agree that a single team will investigate chemical events requiring outside review. This investigation team should comprise already-appointed representatives from all stakeholder groups and agencies, including members of the public who can effectively represent and communicate with local officials and the affected public. Incident findings should be documented in a single comprehensive report that incorporates the findings, proposed corrective actions, and concerns of the various oversight agencies.

ESTABLISHING A SAFETY CULTURE

The committee believes that the JACADS and TOCDF safety programs and performance have been and continue to be adequate to ensure that chemical demilitarization operations are being conducted safely. Even so, there is considerable opportunity for improvement. Many of the incidents that have occurred at JACADS and TOCDF could have been significantly mitigated—if not prevented—had a true "safety culture" been in place and functional at the time.

Recommendation 12a. Much of the needed improvement in safety at chemical weapons facilities can come from increased attention to factors that contribute to and/or cause chemical events. For example, the Program Manager for Chemical Demilitarization and chemical demilitarization facility managers should ensure that standard operating procedures are in place, up to date, and effective, performing hazard operations analyses on new process steps and design changes even when such changes are viewed as trivial and recognizing that chemical hazards are posed by things other than agent (e.g., waste).

Recommendation 12b. Management at the Tooele Chemical Agent Disposal Facility (TOCDF) and the new third-gen-

eration facilities should develop or identify and implement programs that will result in the establishment of a pervasive, functioning safety culture as well as improved safety performance. In doing so, TOCDF and the new chemical demilitarization sites should draw on experience in the chemical industry, obtained through industry associations or other appropriate venues. The Army should revise the award fee criteria to encourage each new chemical demilitarization site operator to demonstrate better safety performance than that at the older sites.

NEW FACILITY START-UP

The near-term start of operations at the three third-generation chemical demilitarization facilities presents an opportunity to get these facilities off on the right foot. Plant start-up can be a difficult learning experience for new operating crews. It is probable that conditions will arise in plant operation for which no SOP has been written. In these situations operators need an in-depth knowledge of their equipment and its limitations to handle these unusual conditions and maintain plant security. It is common practice in other industries to include “design” people in the start-up crew for new plants.

Recommendation 13. A generous allotment of time should be given to training and retraining chemical demilitarization plant operating personnel to ensure their total familiarity with the system and its engineering limitations. All plant personnel should receive some education on the total plant operation, not just the area of their own special responsibility. The extent of this overall training will be a matter of judgment for plant management, but the training should focus on how an individual’s activities affect the integrated plant and its operational risk. Each facility should develop training programs using the newly designed in-plant simulators to present challenges that require knowledge-based thinking. The training programs should include a process for judging the effectiveness of the training. Including “design” experts in the start-up crew for new plants could be helpful in identifying latent failures in process and facility design.

The committee’s specific findings are paired with the recommendations noted above and presented together in Chapter 6 of this report.

EVALUATION OF CHEMICAL EVENTS at Army Chemical Agent Disposal Facilities

Committee on Evaluation of Chemical Events at Army Chemical
Agent Disposal Facilities

Board on Army Science and Technology

Division on Engineering and Physical Sciences

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Cover: Decontaminated chemical munitions and containers at Johnston Atoll Chemical Agent Disposal System. Photographs for composite image courtesy of Colin Drury.

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Preface

For over half a century the United States has maintained a stockpile of chemical weapons at Army depots distributed around the country. These weapons are now obsolete, and some have deteriorated to an alarming extent. Since 1990, in response to P.L. 99-145 and, later, P.L. 102-484, the Army's Program Manager for Chemical Demilitarization (PMCD) has been engaged in active destruction of the chemical weapons stockpile. Operation of the two initial chemical agent demilitarization facilities utilizing incinerator technology—Johnston Atoll Chemical Agent Disposal System (JACADS) and Tooele Chemical Agent Disposal Facility (TOCDF) (see Appendix A)—has achieved destruction of more than 23 percent of the original chemical agent tonnage (U.S. Army, 2001a) but has not been without incident. A number of chemical events have resulted in various levels of chemical agent migrating at higher than anticipated levels into areas within the plants themselves, and in a few incidents small amounts of chemical agent have been released into the ambient atmosphere (see Appendix B). Although none of these incidents resulted in agent releases large enough to be measured at the chemical demilitarization plant perimeters (U.S. Army, 2001c) and thus posed no threat to nearby communities, they did raise concern among affected public officials and citizens about the fundamental safety of incineration-based chemical demilitarization facilities, particularly the three third-generation incineration facilities scheduled to begin operation at depots near Anniston, Alabama; Umatilla, Oregon; and Pine Bluff, Arkansas.

STATEMENT OF TASK

This report was motivated by congressional concern that incidents at JACADS and TOCDF might indicate systemic safety issues with either the technology or the management and operational systems employed at those two initial chemical demilitarization facilities.

The Committee on Evaluation of Chemical Events at

Army Chemical Agent Disposal Facilities, convened in April 2001 by the National Research Council (NRC), was charged with the following statement of task negotiated between the Army and the NRC:

The National Research Council will assemble a committee to evaluate chemical events that have occurred at the Johnston Atoll Chemical Agent Disposal System (JACADS) and the Tooele Chemical Agent Disposal Facility (TOCDF). The committee will:

- review process technology, operational activities (including training, operations and maintenance), and management by both the Army and its contractors to identify the causes of chemical events
- review applicable risk management and safety programs
- review emergency response activities that have occurred as a result of each chemical event, including information dissemination
- review actions and changes that have occurred in response to each chemical event and evaluate the impact and adequacy of these actions and changes
- visit JACADS and TOCDF to review facility configurations and to meet with personnel involved with operational activities, facility management, and emergency response
- make recommendations regarding improvements in operational activities, facility management, and emergency response
- review and recommend the needs to enable credible and more rapid investigation and corrective actions in response to future chemical events at chemical demilitarization sites, including consideration of needs of external stakeholders (e.g., regulators and concerned public).

To ensure that new facilities for the destruction of chemical agent are operated as safely as possible, the NRC was further asked to recommend how lessons learned from the

events at JACADS and TOCDF should influence future operations, particularly at the new facilities in Alabama, Oregon, and Arkansas scheduled for completion and initial operations in the near future.

COMMITTEE COMPOSITION AND PROCESS

Committee members brought to their task extensive experience in chemical process engineering, chemical plant operations, human factors and ergonomics, industrial engineering, risk assessment and management, atmospheric sciences, environmental chemistry, toxicology, environmental regulations and law, emergency management, and public involvement and community relations (see Appendix H). In conducting this study, committee members drew on insights gained from their experiences in academia, chemical and related industries, federal and state agencies, private sector laboratories and consulting firms, and a law firm.

The committee first met as a whole in Washington, D.C., in May 2001 to hear Army briefings on JACADS and TOCDF general operations and chemical events. (Appendix I lists the committee's several meetings.) In early June many committee members attended an informational meeting on Capitol Hill hosted by Congressman Bob Riley (R-Ala.), who represents the region around the Anniston Chemical Demilitarization Facility, which is currently undergoing systemization and preoperational testing. Local government officials, emergency management professionals, and concerned citizens from the area near Anniston, Alabama, shared their perspectives with the committee. Committee members and staff also visited PMCD and its supporting contractors located at the Aberdeen Proving Ground, Maryland.

The committee made site visits to JACADS in late June 2001 and to TOCDF in late July 2001 where it investigated the operational history, management procedures, and evaluations of and responses to chemical events at these facilities and discussed these issues with contractors and PMCD personnel at many levels. At a meeting at Woods Hole, Massachusetts, in October 2001 the committee completed the bulk of the data-gathering process as well as much of the initial draft of its report. The November 2001 meeting, in Washington, D.C., was dedicated to completing the initial report draft. A portion of the committee also visited Anniston, Alabama, in early December 2001 to inspect a completed third-generation incineration facility and a storage depot with an extensive nearby population base. As a part of the visit the committee visited the County Emergency Response Facility, met with County Commissioners, and participated in a public meeting. A draft report suitable for NRC prereview editing was produced subsequent to the Anniston visit. A final committee meeting in January 2002 focused on review-

ing this draft, including refining the report's findings and recommendations.

The committee consulted with and received input from many stakeholders, both principals and agents, including personnel assigned to the office of the PMCD and its support contractors; contractor and subcontractor personnel responsible for operating chemical demilitarization facilities; former employees of chemical demilitarization facilities; congressional, state, and local officials; members of state citizen advisory committees; members of citizen activist groups; and local citizens. (See Appendixes C, D, and I.)

The committee has also benefited from previous NRC reports on the chemical demilitarization program. Many of these reports were prepared by a standing NRC committee, the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (the Stockpile Committee), which evaluates aspects of the disposal program at the request of the Army. Several of the Stockpile Committee reports provided background for this committee's study.

In preparing, reviewing, printing, and distributing this report, the National Research Council (NRC) and this committee are acting as an expert *agent* for several principals, including the U.S. Congress; the Army, which contracted with the NRC to perform the study; and the U.S. public.

The committee's goals for this report were to respond, as thoroughly as feasible in the short time allotted, to the concerns stakeholders have expressed about past chemical events at JACADS and TOCDF, to determine the impact of these events on ongoing operations at TOCDF, and to assess the implications of these events for the safe and efficient operation of incineration-based chemical demilitarization facilities scheduled to begin operation at Anniston, Umatilla, and Pine Bluff.

The committee greatly appreciates the support and assistance of National Research Council staff members Bruce A. Braun, Margaret Novack, Nancy Schulte, Bill Campbell, Jim Myska, Sonnett Hossanah, Pamela Lewis, and Carter Ford in the production of this report.

NOTE: Following preparation of this report two chemical events, one at TOCDF on July 15, 2002, and one at JACADS on August 12, 2002, have taken place. Although these incidents occurred after the committee completed its analysis, they are similar in nature to events analyzed by the committee and reinforce the validity of the findings and the utility of the recommendations presented in this report.

Charles E. Kolb, *Chair*
Committee on Evaluation of
Chemical Events at Army Chemical
Agent Disposal Facilities

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Richard J. Ayen, Waste Management, Inc. (retired)
Judith A. Bradbury, Battelle Patuxent River
Dennis R. Downs, Utah Department of Environmental
Quality
Charles A. Eckert, Georgia Institute of Technology
Richard S. Magee, Carmagan Engineering

Lewis S. Nelson, New York City Poison Control Center
George W. Parshall, E.I. DuPont de Nemours & Co. (re-
tired)
William R. Rhyne, Informatics Corporation, and
Palmer W. Taylor, University of California, San Diego.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Royce W. Murray, University of North Carolina, Chapel Hill. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Acronyms and Abbreviations

ACAMS	automatic continuous air monitoring system
AEGL	Acute Exposure Guideline Level
AMC	Army Materiel Command
ASC	allowable stack concentration
CAC	Citizens Advisory Commission
CAMDS	Chemical Agent Munitions Disposal System
CDC	Centers for Disease Control and Prevention
Chem demil	chemical demilitarization
CSDP	U.S. Chemical Stockpile Disposal Program
CSEPP	Chemical Stockpile Emergency Preparedness Program
CWC	Chemical Weapons Convention
CWWG	Chemical Weapons Working Group
DAAMS	depot area air monitoring system
DCD	Deseret Chemical Depot
DEQ	(Utah) Department of Environment Quality
DFS	deactivation furnace system
DoD	Department of Defense
DSHW	(Utah) Division of Solid and Hazardous Waste
DWL	drinking water level
ECP	engineering change proposal
ECR	explosive containment room
EG&G	Edgerton, Germerhausen and Grier (a contracting company)
EMIS	Emergency Management Information System
EOC	emergency operations center
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FPD	flame photometric detector
GAO	General Accounting Office
GB	sarin (a nerve agent)
GC	gas chromatograph, gas chromatography
GPL	general population limit

H	sulfur mustard
HAZMAT	hazardous material
HAZOP	hazardous operation
HD	sulfur mustard (distilled)
HDC	heated discharge conveyor
HRA	health risk assessment
HT	vesicant mixture: 60 percent agent H and 40 percent bis[2(2-chloro-ethylthio)ethyl] ether
HVAC	heating, ventilation, and air conditioning
JACADS	Johnston Atoll Chemical Agent Disposal System
LIC	liquid incinerator
MDB	munitions demilitarization building
MOU	memorandum of understanding
MPF	metal parts furnace
MSD	mass spectrometric detector
NARAC	National Atmospheric Release Advisory Center
NRC	National Research Council
OSHA	Occupational Safety and Health Administration
PARDOS	partial dosage
PAS	pollution abatement system
P.L.	public law
PLL	programmatic lessons learned (program and database)
PMACWA	Program Manager for Assembled Chemical Weapons Assessment
PMATA	Product Manager for Alternative Technologies and Approaches
PMCD	Program Manager for Chemical Demilitarization
PMCDSD	Project Manager for Chemical Stockpile Disposal
QA	quality assurance
QC	quality control
QRA	quantitative risk assessment
RCRA	Resource Conservation and Recovery Act
RIR	recordable injury rate
SAIC	Science Applications International Corporation
SBCCOM	U.S. Army Soldier and Biological Chemical Command
SHA	systems hazard analysis
SOP	standard operating procedure
TOCDF	Tooele Chemical Agent Disposal Facility
TWA	time-weighted average
UPA	unpack area
USACAP	U.S. Army Chemical Activity Pacific
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
U.S.C.	United States Code
VX	a nerve agent
WCL	waste control limit
WPL	worker population limit
5X	level of decontamination (suitable for commercial release)